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Keywords

Lean, analysis, continuous, process, industry, supply, chains

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LEAN AND THE ANALYSIS OF CONTINUOUS PROCESS INDUSTRY SUPPLY CHAINS

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Abstract

The lean approach is a well established philosophy in the manufacturing industry. Due to increasingly competitive global markets, the scope of application for this way of thinking is widening, and continually evolving to become suitable for application into new areas - the continuous process industry being a key example. In response, this paper investigates the efficacy of lean within continuous process supply chains and the 'cherry-picking' approach applied by some. A comprehensive and novel mapping approach is presented, in an effort to integrate the business and operational functions. Conclusions are drawn on the advantages and limitations of the methodology, and further possible directions for research.

Keywords: Lean, supply chain management, process industry.

1. Introduction

In today's ever more competitive environment, the idea of lean thinking, as coined by Womack and Jones [1] has become a staple for the manufacturing industry, where being flexible to constantly changing and more demanding customers has become essential for survival and growth, rather than an option. Since its rapid spread among the manufacturing community from the nineties onwards a myriad of diverse industries are having to challenge their thinking [2], and constantly question every process. Management now not only need to manage effective budgets and deliver quality to the customer, they should also develop and sustain a culture of continuous improvement within their organisation. This creates opportunity to identify paths to long term strategic advantage. (See also Fujimoto [3]).

For the majority of organisations which take on a lean initiative, it is the beginning of a successful journey into an environment of continuous improvement, as the very nature of lean is iterative. Once an organisation has started to follow the lean approach, opportunities for improvement should continually present themselves, leading to a continuous analysis of the material and information operations, which in itself will lead to increasing flexibility to customer demand.

When businesses try to extend the lean philosophy throughout their respective supply chain networks, it can often become problematic; with companies finding themselves grinding to a halt after taking the first few critical steps, if the wrong implementation strategy is followed.

The traditional viewpoint regarding the applicability of lean techniques has shifted from high volume, low variety manufacture, to also encompass generic discrete manufacturing facilities, as the wave of "Job-shop" lean research [4,5] exemplified. However, one of the less travelled paths for the implementation of these techniques is the continuous process industry.

The most common problem when implementing lean within an organisation, is the tendency of the management to 'cherry-pick' a few key lean tools. They implement lean initiatives, interpreting the methodology how they feel it best suits their facility. Individual aspects are picked out, resulting in one or two lean ideas being implemented, with the organisation operating under the pretence that they have become 'lean', but find improvements plateau after some initial success. Another common problem is the fact that the information flow around the system is ignored, while the material flow is constantly under scrutiny. This is a direct result of organisations becoming too focussed on the application of 'lean tools' instead of a culture driven approach, while management under utilise their potential influence and neglect the need for total commitment. This paper discusses and draws comparisons between the needs of discrete and continuous environments, and the possible suitability of the 'cherry-picking' approach. The applicability of the lean philosophy within the continuous process sector is introduced through a review of literature on lean and its application within the supply chain. A comprehensive and novel mapping approach is then proposed that integrates key business indicators with traditional mapping techniques and quality initiatives, providing a dynamic view and quantification of the results through models developed in discrete event simulation software. The paper concludes by discussing the advantages and limitations of the methodology, and further directions that can be developed from the research.

2. Literature Review

Through their participation in the International Motor Vehicle Programme (IMVP), which analysed the performance differences between Japanese and Western automotive industries, Womack and Jones [1] marked the beginning of the realisation by Western automotive industry that becoming globally competitive was crucial if organisations wanted to remain in business and maintain existing, or identify new markets. Able to see the increasingly long term competitive stance Japan's manufacturers were taking; western industry had no choice but to try and adopt this new, and in places, counter-intuitive way of thinking. The Toyota Production System (TPS) was adapted under the title of Just-In-Time (JIT) manufacturing, and US and European manufacturers began their lean journey. Storhagen [6] discusses this transition and identifies the different implementation perspectives from East to West due to operational and cultural differences. It is suggested that the establishment of confidence within the workforce is key to the uptake and success of lean, which is achieved through all levels of management understanding and committing to the essence of the lean approach – i.e. a *philosophy of continuous improvement*, rather than just a set of tools or techniques [7]. In order to successfully do this, organisations should not merely 'transfer' the methodologies, but work towards recognising their own cultural profile, and create adaptation strategies for implementation [8]. From this it can be deduced that insufficient effort is made by management beforehand, to establish a much needed support structure for changes to be made in the company wide philosophy.

To emphasise the continuous and expanding nature of the lean approach throughout the modern business world, Figure 1. illustrates the lean cycle, outlining the four key elements that should be inherent within any lean initiative (whether applied locally, or within the total supply chain context).

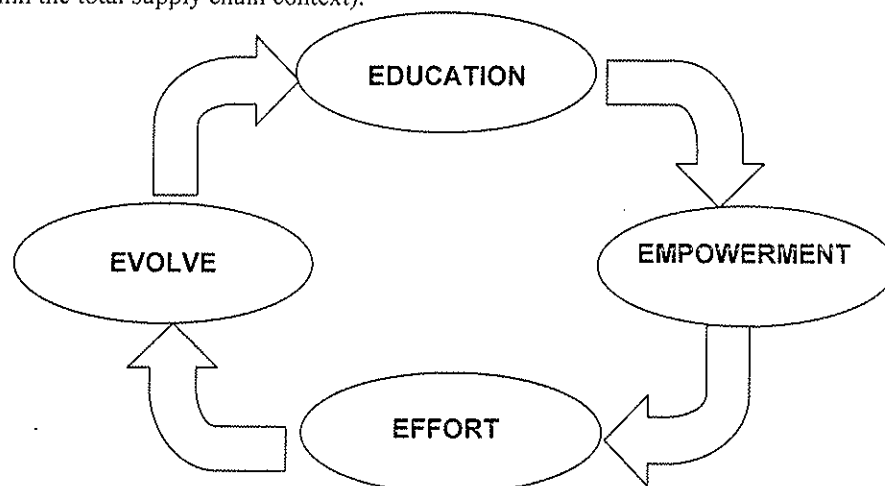


Figure 1. The Lean Cycle

- *Education* refers to the culture change necessary for a lean initiative to work. It also refers to teaching employees how to 'think lean', i.e. what the seven forms of waste are, and how to tackle them.
- *Empowerment* refers to the power and authority given to employees to identify problems and solve issues within the organisation. In other words, ownership of the process, and how it is managed. Knowing that their voice will be heard, and their opinion discussed rather than dismissed.
- Empowerment and education work hand in hand through the use of kaizen events where the mapping and analysis of a process leads to physical changes being made.
- *Effort* describes the work put in to identify opportunities for improvement, and kaizen events – the need to constantly be aware of the work environment and how it can be changed for the better.
- *Evolve* emphasises the cyclical nature of continuous process improvement, and also the need to consider the environment outside of the facility. Extending lean thoughts throughout the supply chain is the only way to fully implement lean successfully, whereby suppliers and customers adhere to the same working principles.

It can be said that the application of lean has been successful in a number of diverse industries and has had limited success in others. The transfer of lean methodologies to the continuous process industry has been explored. While optimisation through the application of lean thinking has been rare [9] it continues to present new boundaries for the implementation of continuous improvement techniques. The process industry differs from discrete manufacturing in a number of ways. Often, they have little or no opportunities for Work In Progress (WIP) to accumulate, because there are no discrete processes for which inventory can queue between, or act as a buffer. Winters, Price et al [10] provide the following statement regarding the characteristics of the process industry:

"Process industries are typically characterized by very high fixed capital, concentrated in a small number of workstations. The production equipment is often physically large, and relatively fixed in nature. In most discrete

manufacturing operations, the capital investment is smaller and spread across many workstations. As a result, continuous process manufacturing operations are less flexible to change than discrete manufacturing operations."

The work of Fransoo and Rutten [11] considers the differences inherent in various process industries, leading to the identification of two groups: flow process and batch process industries. A summary of the characteristics of both groups can be found in Table 1. (adapted from [11]).

Flow Process Industries	Batch Process Industries
High production speed, short throughput time	Long lead time, high Work In Progress (WIP)
Clear determination of capacity, one routing for all products, no volume flexibility	Capacity not well defined (different configurations, complex routings)
Low product complexity	More complex products
Low added value	High added value
Strong impact of changeover times	Less impact of changeover times
Small no. of production steps	Large no. production steps
Limited no. of products	Large no. of products

Table 1. Process Flow/Batch Flow Characteristics [11]

Van Donk and Fransoo [12] go on to categorise research conducted on the process industry into three areas: Production Planning and Control (PPC), empirical studies and process industry characteristics. Therefore, the methodology proposed in this paper is well positioned, having consolidated these characteristics into one tool.

Billesbach [13] has conducted research into the application of lean principles within the textile industry, implementing a Kanban based solution for materials handling within the facility, while Cook and Rogowski [14] have extended this view along the supply chain.

The discussion of the transferability of ideas to the process industry from discrete manufacture is a recurring theme. Cook [14] discusses a successful implementation of Just-In-Time (JIT) principles in Dow Chemical-North America, quoting improvements such as demand forecast accuracy improving by 25%, lead time reduced by 25%, and lead time variability reduced by 50%, while Lehtonen [15] advocates the use of simulation, demonstrating through its use [16] the benefits of the application of JIT techniques.

The proposed methodology reaches beyond this view, incorporating a number of key techniques, as well as emphasising the cultural change that must be adopted by any organisation wanting to start a journey of continuous improvement. As in discrete manufacturing, in order to realise the full potential of such improvement methods, it is essential to focus on the whole supply chain.

3. Research Methodology

The Supply Chain Improvement Method for Process Industries (the SCIMPI model) has been developed in order to address the scope for a comprehensive mapping and analysis framework within the process industry, which provides a dynamic approach on both the operational and business level. Instead of using the cherry-picking approach, which alone can be time consuming and lead to inappropriate application, the SCIMPI model aims to bring together all of the most suitable high-impact techniques which guide strategic direction and planning.

Figure 2. is an outline of the SCIMPI approach. The well established six sigma Define Measure Analyse Improve Control (DMAIC) framework is used as a platform providing direction for the continuous improvement implementation. In addition to this, another stage has been added at each end of the DMAIC cycle. *Lead* and *Learn* to launch the initiative, and *Enterprise* to restart the cycle of continuous improvement.

Stage 1

Lead and Learn is the first step, directing the user to establish cross-functional teams and provide the grounding for continuous improvement fundamentals (5S, SMED, TPM and so on) that will be used throughout the SCIMPI approach. This is where the cultural change within the organisation begins, and the realisation of empowerment is introduced. The role of simulation, and the tools used in all of the following stages should be introduced and understood before moving on any further with the SCIMPI model.

Stage 2

At the *Define* stage, an enhanced version of Value Stream Mapping (VSM) is used, incorporating the identification and quantification of financial objectives, measures, targets and initiatives for each stage. The Balanced Scorecard tool is an integral part of this stage, providing focus on applicable lean initiatives that may be pursued. This process mapping stage also provides the direction and scope for smaller scale, data intensive projects, which are tackled with six sigma theory.

Stage 3

The *Measurement* stage introduces simulation to record the current state of operations in a dynamic environment. The Balanced Scorecard, Activity Based Costing, and Value Velocity values are used within the simulation software to provide economic traceability and key costing indicators at every process, be it business or operational.

Stage 4

At the *Analysis* stage of the approach, the current state simulation model developed in the Measure stage is used, along with SPC techniques to analyse the highlighted process(es). Here, variation is addressed, as well as information and product flow. Any anomaly is refined to an optimum situation within the simulation model, allowing off-line flexibility to the analysis, causing the minimal disturbance to the real system.

Stage 5

Stage 5, *Improve*, guides the implementation team brought together in the *Lead and Learn* stage to apply the most high impact lean tools for the Continuous Process Industry. These high impact tools are 5S, also known as Good-Housekeeping, Single Minute Exchange of Die (SMED), Total Productive Maintenance (TPM), and Design of Experiments (DOE). 5S (the essence of which should be introduced in the first stage) is used in this case to make everything in the facility standardised and in the right place, at the right time. Due to the very nature of the processes within continuous process industries (that is, extremely expensive to be off-line) SMED is used to optimise the changeover routine, so that down-time is minimised. TPM is also used to target any possible downtime by providing reliable machinery and/or processes, which underpins the efforts made in obtaining a lean facility. Leading on from this, DOE is applied to any highlighted process (on-line or off-line using the simulation model, as appropriate), so that the optimum results can be realised for that given process.

Stage 6

The *Control* stage is where standardised work is introduced so that the improved procedures and processes that have been developed in the previous stages are not lost, and any newcomer to the system has a record of how tasks should be approached to fulfil their potential. A future state simulation model will have been developed within the Analysis stage, which is maintained at this point so that demonstrations can be provided for each process, as well as a dynamic illustration of the system. Customer focus should be emphasised throughout the SCIMPI approach, but is mentioned at this stage as, because customer demands of quality and so on are constantly changing. These changes need to become the driving point for future change.

Stage 7

The final stage of the SCIMPI approach, *Enterprise*, depicts the expansion of the previous stages towards customers and suppliers. At this point, relationships need to be started with key suppliers, with a view to extending the SCIMPI approach throughout the supply chain. It is suggested that a number of personnel from the cross-functional team put brought together in *Stage 1*, should begin the SCIMPI analysis process in the supplier organisation, leading the efforts towards *Stage 7*, at which point new champions will be made that can demonstrate and lead efforts within their own organisation, as well downstream to their own suppliers. In this way, it can be demonstrated to the new teams by employees who have had experience and success using this model, and go on instigate cultural change, as it is often difficult for management to get this message across effectively.

Being continuous in nature, the Supply Chain Improvement Methodology is only the start of any continuous improvement implementation. When new SCIMPI teams are nurtured in *Stage 7*, taking the approach to their own facilities, the process of analysis starts again within the starting organisation and hence forth, the supply chain in question will embark on an dynamic and journey of change that will transform the way in which process industry supply chains integrate, resulting in flexible, competitive supply chains, with the ability to compete in any given market.

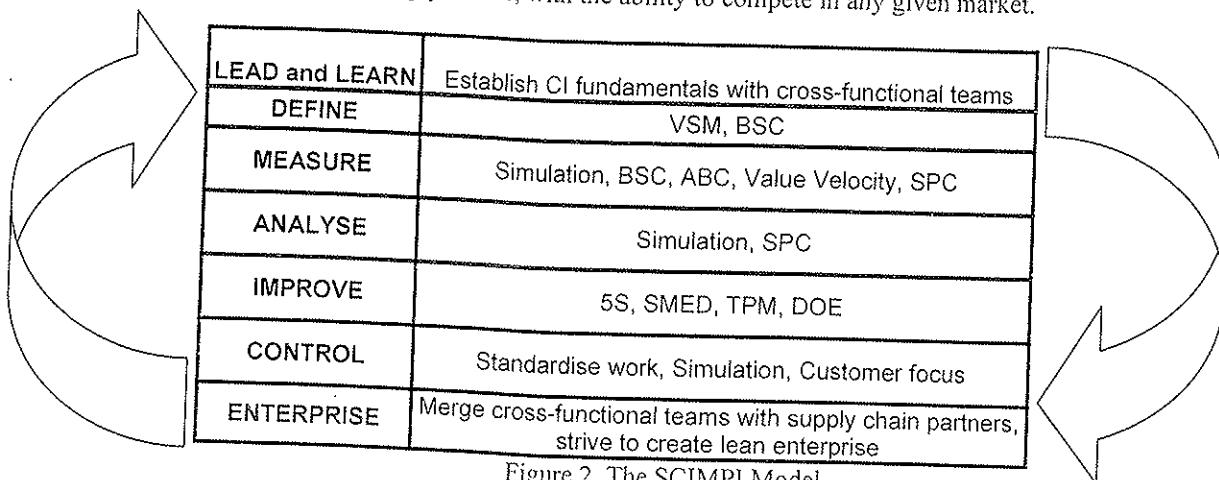


Figure 2. The SCIMPI Model

4. Discussion

The techniques brought together in the formation of the SCIMPI approach have been chosen in an attempt to provide a comprehensive and focussed analysis tool for members of the process industry wishing to improve their competitive stance within their respective industries, and realise the potential of becoming competitive on a supply chain scale.

The SCIMPI methodology attempts to increase the scope of mapping and analysis, and target the four key areas of *Mapping, Business, Improvement* and *Variation* using specific tools and techniques. Figure 3. depicts the four key areas addressed, and illustrates the relationships between these and the techniques used within the SCIMPI model.

As can be seen in Figure 3., the largest concentration of techniques is used to address the *Mapping* and *Business* sections of the SCIMPI model. Value Stream Mapping is normally applied to a manufacturing system on its own, under the misconception that it will facilitate a lean implementation. In fact, this is not the case, as a whole strategic philosophy throughout the supply chain is needed in order for a system to be running at a truly lean level. The VSM tool itself has little impact on variation within a system, and no feedback indicative of the costs involved at each process. To achieve this, VSM needs to be used in conjunction with other tools. This view looks beyond VSM as giving a quick, succinct overview of where waste is present, and develops the idea of the mapping process itself becoming a continuous tool, constantly being updated by simulation models. The proposed methodology leads the user through the lean cycle described in Figure 1. and facilitates ongoing supply chain analysis. In this case, VSM underpins the whole strategy, using the additional data supplied through the addition of the Balanced Scorecard and Activity Based Costing techniques. Used in conjunction with 5S, a foundation is made for the *Business* case to be improved in the subsequent SCIMPI stages.

Although this first stage of the methodology provides valuable information for the organisation, the necessity for identifying the business case during a continuous improvement program has been realised through the integration of the balanced scorecard approach (BSC), activity based costing (ABC) and the value velocity index. Being both a management and data driven costing system, BSC lends itself to such a methodology, providing key business process strategic data, while ABC is used to identify indirect and direct costs associated with production, so that an economic break even point can be drawn upon. When combined with the value velocity index, these tools can indicate long term strategic direction, which in turn leads to a stronger market position compared to the competition. ABC lends itself to the continuous process industry, as errors within a continuous process environment are extremely expensive, and ABC addresses this through complete traceability of its actions. The Value Velocity index is used as an indication of supply chain performance and its practical usage, by benchmarking the amount of profit per day experienced at any point in the supply chain.

Both of the included costing tools are used to highlight the economic advantages of change to the various hierarchical levels of management, whose participation provides the keystone to any such successful program of change, and also presents the long term strategic needs of the organisation, especially when dealing with the many factions included in complicated supply chain structures. The methodology has the potential to fulfil the need for strategic alignment of the many differing interests encountered when considering total supply chains, and also unify the direction of every node within the respective chain through its correct use. This is achieved through the use of multi-disciplinary data, which represents all facets of the supply chain business and operations, such as demand, process times, variation and business data. Statistical Process Control (SPC) is introduced at this stage as a data driven technique that controls the variation within any highlighted process.

Three key lean tools have been used to target process improvement and reliability, also having bearing on the business case itself, by providing a system more flexible to customer demands and changes downstream.

Finally, simulation and six sigma address the variation within highlighted processes through the construction of control charts, as well as providing dynamic vision to the mapping phase. Although simulation could be seen to address the *Business* and *Improvement* case of an organisation or supply chain, this is only the case when costing techniques etc are applied to the current state model itself. That is, without the use of artificial intelligence and so on, simulation relies on the input of the user in order to model the future state – it will not provide a solution of its own accord. SCIMPI brings together the four key areas necessary for a comprehensive approach to make significant changes and explore opportunities for improvement on all levels, as well as providing a starting point for an organisation wanting to embark on a journey of continuous improvement.

When considering the applicability of lean within continuous process industries, it can be said that it is well suited to such environments. Not all lean techniques lend themselves to such situations, so the most suitable ones must be selected and implemented as put forward in the SCIMPI model. However different process industry environments are to discrete process organisations, the same implementation issues still exist and must be managed correctly – namely the SCIMPI approach needs to have the backing of everyone from the top management down within the organisation.

If managed in this way, there could be a proliferation of SCIMPI teams who drive and lead this initiatives, developing throughout organisations supply chains.

When observing the two different process industry characteristics as put forward by Fransoo and Rutten (flow process and batch process), it could be said that due to the inherent characteristics of batch process industries, the SCIMPI model is not entirely practical due to the long lead times and large quantities of Work In Progress. In this case, the SCIMPI approach would need to be adapted or target smaller scale projects, leading to a macro level analysis once a foundation of smaller analyses have been made.

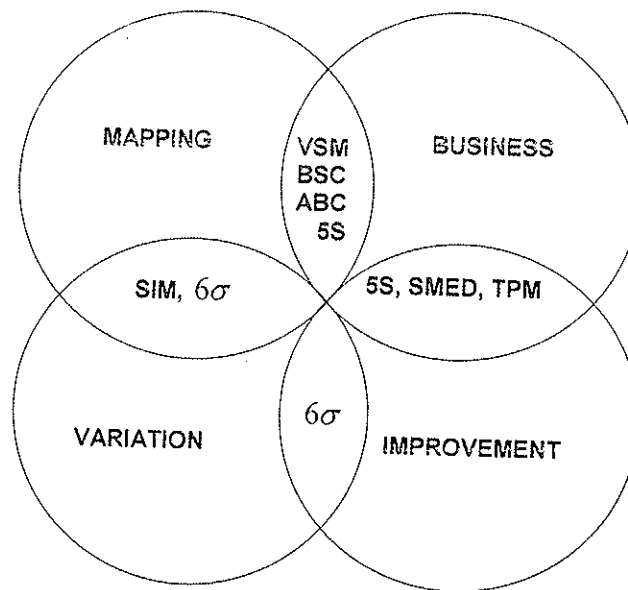


Figure 3. Scope of SCIMPI approach

5. Conclusions

The SCIMPI model developed in this paper could be seen to have much scope, with a number of advantages but which in turn could present a number of limitations. It provides a focussed and directed approach to continuous improvement implementation within process industry supply chains, and has cherry-picked what the authors believe to be the most effective and high impact improvement techniques for process industries. By providing this methodology, the arduous and time consuming task of management looking at various improvement philosophies, tools and techniques (which may lead to their commitment being spread too thinly) is reduced. When confronted with a number of tools and techniques, it is easy to attempt implementation efforts for a few, and see if they happen to work. Unsure of which techniques to follow, inappropriate efforts may be made, leading to high resource usage only to obtain small incremental improvements, meaning that economic justification of such tools makes it an unviable approach.

On the reverse side of the coin, the SCIMPI model could be seen as a complex solution, which is only applicable, or available to large industry players. Those in a dominant position within the supply chain may be the only organisations able to get the other supply chain partners to start any sort of initiative. Being a comprehensive approach, the SCIMPI model needs to be taken as a comprehensive tool that is every part of the approach needs to be adhered too, otherwise the expected result of an analysis that provides accurate, dynamic mapping, with strategic economic cases leading to competitive strategies being formed, will not deliver.

In line with the lean vision, the next stage of development for the SCIMPI approach is the production of clear, concise, visual instructions so that organisations can follow the methodology and start the implementation of continuous improvement. An aid to this would be the design of a tailored simulation package, similar to that of McDonald, Van Aken et al [17], but providing focus on the business case through the integration of the discussed costing models. Leading from this, virtual environments for teaching the SCIMPI model could be created, following on from the work of Chi, Pepper et al [18].

In order to extend the scope of the SCIMPI model still further, an examination of the relationships needed for effective supply chain management could be considered, leading to commentary on the blend of lean and agile techniques needed within the process industry, and whether the decoupling point would experience a shift due to the nature of the sector. Steps to incorporate strategic planning and market analysis would also be beneficial, to provide a broader scope for organisations once they have started the SCIMPI cycle. This has potential to lead on from the strategic alliance stage, and develop frameworks such as design for lean or design for six sigma, and provide a design for continuous improvement, or SCIMPI, which again will target both the economic and operational levels and strategies within a given supply chain.

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